# GPS Wing Program Update

***International Satellite Navigation Forum***

*Moscow, Russia*

*9 April 2007*

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GPS Wing
Los Angeles AFB, CA

# Overview

- **System Improvements & Modernization**
  - GPS Constellation Status
  - Modernizing Space and Control Segments
- **Interoperability & International Collaboration**
- **Summary**

# GPS Constellation Status as of 9 Mar 07

## 29 Healthy Satellites

### Baseline Constellation: 24

- **14 Block IIA satellites operational**
- **12 Block IIR satellites operational**
- **3 Block IIR-M satellites operational**
  - IIR-15(M) launched 25 Sep 06
    - 17 days from launch to on-orbit ops
  - IIR-16(M) launched 17 Nov 06
  - 5 additional IIR-M satellites to launch
    - Next launch scheduled for Aug 07, IIR-17(M)
- **Since Dec 93, U.S. Government met/exceeded civil GPS service performance commitments**
  - SPS Performance Standard (PS)
- **Additional pseudo-random codes allow constellation size of up to 32 satellites**
- **U.S. Government continues to demonstrate its commitment to superior GPS service**

# IIR-15(M) Launch
# 25 September 2006


# IIR-16(M) Launch
# 17 November 2006

# GPS constellation – Delivering excellent performance

| | Orbital Slot | SVN | PRN | Block | URE |
|---|---|---|---|---|---|
| A-plane | A-1 | 39 | 9 | IIA | 1.11 |
| | A-2 | 25 | 25 | IIA | 2.61 |
| | A-2 | 52 | 31 | IIR | 0.14 |
| | A-3 | 38 | 8 | IIA | 0.36 |
| | A-4 | 27 | 27 | IIA | 2.13 |
| B-plane | B-1 | 56 | 16 | IIR | 0.45 |
| | B-2 | 30 | 30 | IIA | 2.06 |
| | B-3 | 44 | 28 | IIR | 0.68 |
| | B-4 | 35 | 5 | IIA | 0.6 |
| | B-5 | 58 | 12 | IIR | 0.16 |
| C-plane | C-1 | 36 | 6 | IIA | 1.05 |
| | C-2 | 33 | 3 | IIA | 0.36 |
| | C-3 | 59 | 19 | IIR | 0.38 |
| | C-4 | 53 | 17 | IIR | 0.21 |
| | C-5 | 37 | 7 | IIA | 0.69 |

| | Orbital Slot | SVN | PRN | Block | URE |
|---|---|---|---|---|---|
| D-plane | D-1 | 61 | 2 | IIR | 0.6 |
| | D-2 | 46 | 11 | IIR | 0.22 |
| | D-3 | 45 | 21 | IIR | 0.69 |
| | D-4 | 34 | 4 | IIA | 1.29 |
| | D-6 | 24 | 24 | IIA | 1.08 |
| E-plane | E-1 | 51 | 20 | IIR | 0.33 |
| | E-2 | 47 | 22 | IIR | 0.5 |
| | E-3 | 40 | 10 | IIA | 0.45 |
| | E-4 | 54 | 18 | IIR | 0.49 |
| F-plane | F-1 | 41 | 14 | IIR | 0.17 |
| | F-2 | 26 | 26 | IIA | 0.09 |
| | F-3 | 43 | 13 | IIR | 0.43 |
| | F-4 | 60 | 23 | IIR | 0.23 |
| | F-5 | 29 | 29 | IIA | 0.52 |
| | F-6 | 32 | 1 | IIA | 1.08 |

**Average URE from 30 GPS SVs: 0.71 m**

**NASA JPL data on Wed Feb 21 17:46:02 2007 (UTC)**

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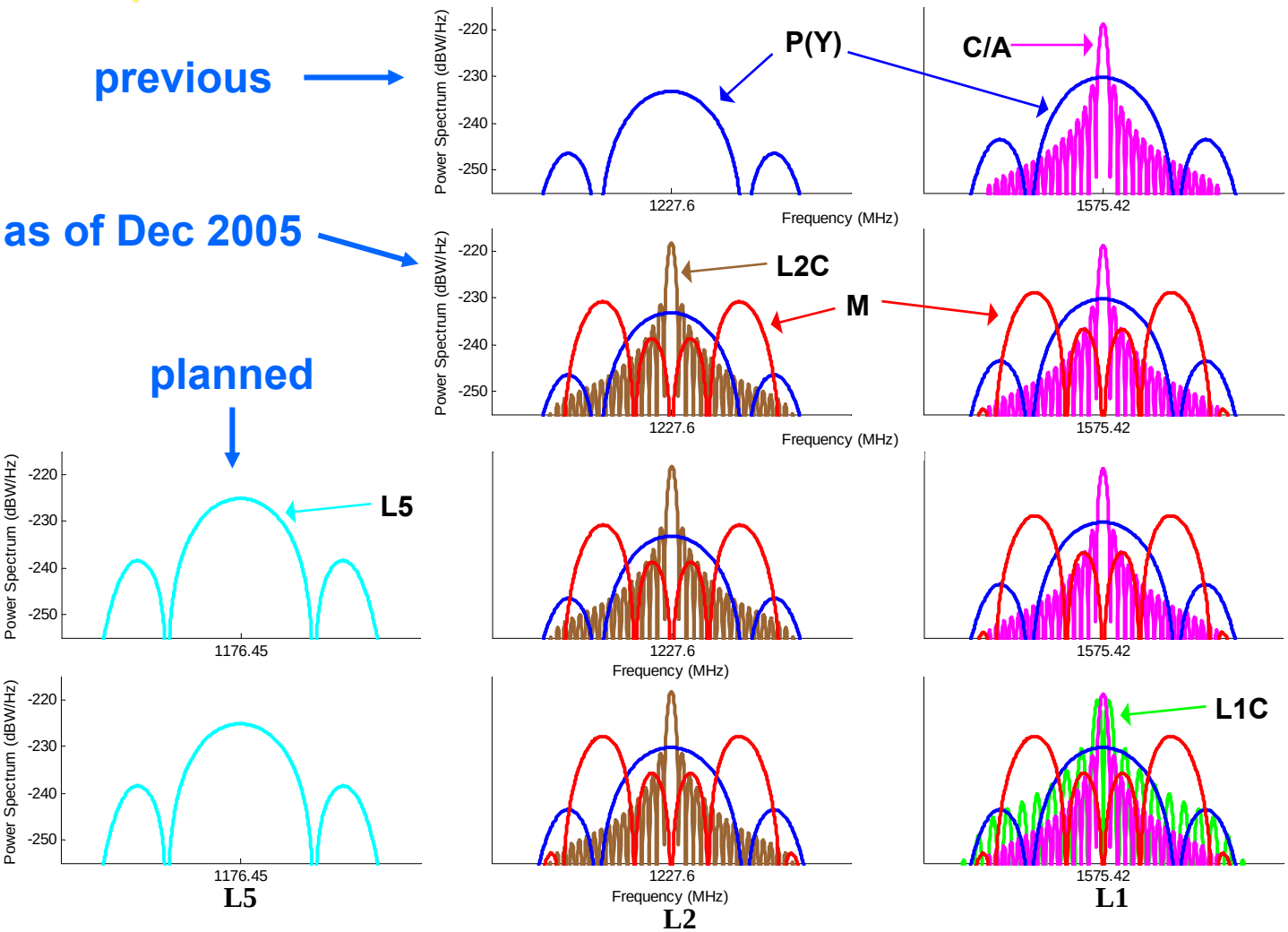
# GPS Modernization – Spectrum

previous

as of Dec 2005

planned



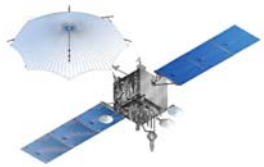

*ARNS Band* *RNSS Band* *ARNS Band*

Block IIA, 1990

Block IIR-M, 2005

Block IIF, 2008

Block III, 2013



(artist's concept)

# Designs of Modernized GPS Civil Signals Provide User Benefits

- Wider RMS bandwidths for improved code tracking performance in noise and multipath
- Wider equivalent rectangular bandwidths for superior resistance to narrowband interference
- Pilot components to track carrier of weak signals
- Forward error control for data message robustness
- Improved spreading codes for lower crosscorrelation
- Three carrier frequencies to support triphase navigation

# GPS Evolutionary "System-of-Systems" Programs

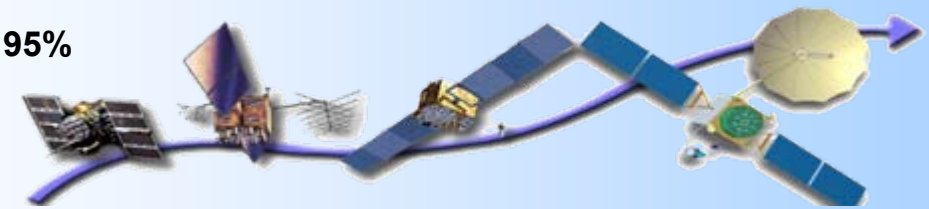
## Space Segment

**Legacy (Block IIA/IIR)**
- Std Service (≤ 6 meters RMS SIS SPS URE)
  - Single frequency (L1)
  - Coarse acquisition (C/A) code navigation
- Precise Service (≤ 2.6 m 95% URE PPS at Zero AOD)
  - Y-Code (L1Y & L2Y)
  - Y-Code navigation

**Modernized (Block IIR-M)**
- 2nd civil signal (L2C)
- M-Code signals (L1M, L2M)
- Anti-jam flex power

**Modernized (Block IIF)**
- 3rd civil signal (L5)

**GPS III (Block III)**
- Increased accuracy
- Increased A/J power
- Signal integrity
- Search and Rescue
- L1C civil signal common w/Galileo, QZSS, & possibly GLONASS



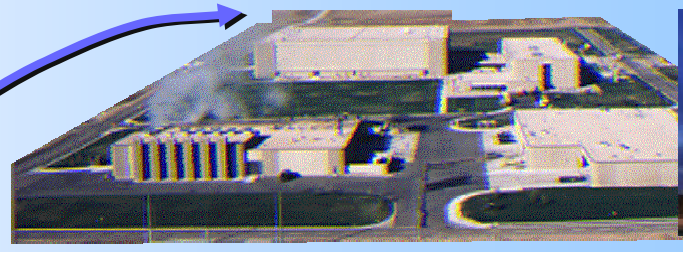
## Ground Segment

**Legacy**
- TT&C
- L1 & L2 monitoring

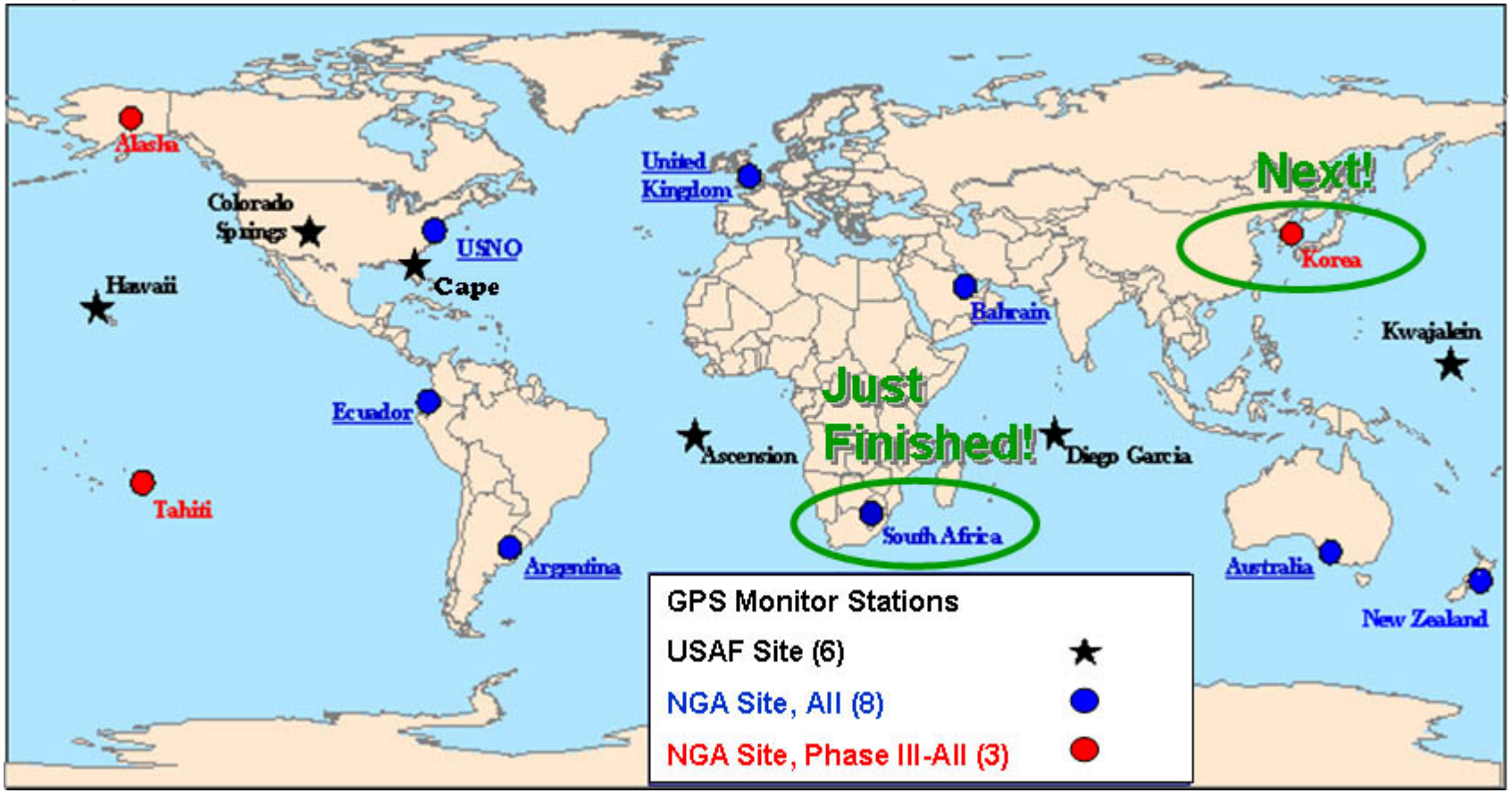
**Upgraded (AEP)**
- IIR-M IIF TT&C
- WAGE, AII, LADO
- NMCS/AMCS

**Modernized (OCX V1)**
- New Architecture
- Signal Monitoring

**GPS III (OCX V2)**
- GPS III TT&C
- Real-Time C2



# Modernizing the operational control segment (OCS): Legacy Accuracy Improvement Initiative (L-AII)




- Each SV tracked by three or more monitor stations over 99% of time
- Zero age-of-data URE improved from ~46 cm to ~27 cm
- L-AII SIS URE improved from ~1.25 m to ~1.05 m

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# GPS-GLONASS Working Group 1 (WG-1)

- **GPS-GLONASS meetings**
  - Dec 04 in Washington D.C., USA
  - Oct 05 in Moscow, Russia
  - Dec 05 in Moscow, Russia
  - Jun 06 in Cocoa Beach, Florida, USA
  - Dec 06 in Yaroslavl, Russia
- **Exploring opportunities for enhanced interoperability and compatibility of civil signals**

# U.S. – Russian Federation
# WG-1 Joint Statement (14 December 2006)

Both parties made "significant progress" understanding benefits to users of a common approach

**United States – Russian Federation**
**GPS/GLONASS Interoperability and Compatibility Working Group (WG-1)**

**Yaroslavl, Ring Premier Hotel, 14 December, 2006**

## Joint Statement

Working Group 1 met on December 13-14, 2006, in Yaroslavl, Russia, and discussed a range of issues. This was the third meeting of the working group. The meeting was highly successful and resolved many questions regarding interoperability and compatibility between the GPS and GLONASS systems. Both sides noted that concerning the question of the use FDMA and CDMA significant progress was made in understanding the benefit to the user community of using a common approach. The Russian side noted that a decision in this regard would be made by the end of 2007.

Both sides agreed that the planned International Satellite Forum 2007 to be held April 9-10, 2007, in Moscow will be a unique opportunity to demonstrate the benefits of GLONASS and GPS interoperability in the Russian Federation for civil applications.

Co-chair
Mark Crews

Co-chair
Vladimir Klimov

# Other International Collaborations

- **Ongoing work with European Union concerning GPS-Galileo civil signal compatibility and interoperability**
  - Emphasis on signals at GPS L1 and L5 frequencies

- **Ongoing work with Japan concerning GPS-QZSS civil signal compatibility and interoperability**
  - Five of six QZSS signals use same signal structures, frequencies, spreading code families, data message formats as GPS or SBAS signals

# GNSS Civil Signal Interoperability

| | Characteristic | Interoperability Benefit |
|---|---|---|
| GLONASS-GPS | • Common time and reference frames, or broadcast offsets | • Navigation solutions can use measurements from different systems |
| ? | • Common carrier frequencies | • Common antenna and receiver front end—lower power and cost; common carrier tracking for higher accuracy |
| | • Similar spreading modulation spectra | • Common-mode dispersive errors removed in navigation solution for higher accuracy |
| GPS (L1C and L5)–GALILEO (E1 OS and E5a) | | |
| | • Common spreading code lengths and common code family | • Lower crosscorrelation sidelobes for better weak-signal reception; common receiver processing for acquisition and tracking |
| | • Common data message structure and encoding | • Common receiver processing for data message decoding and processing |
| GPS-QZSS | | |

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- **Continuing success in GPS sustainment & modernization**
  - New capabilities delivering enhanced performance
  - Developments on track to enhance space and control segments
- **International Collaboration**
  - Excellent cooperation with civil service providers
  - Improving RNSS interoperability/compatibility for GNSS